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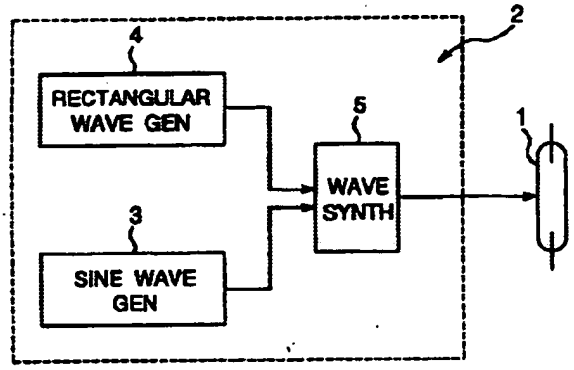
(54) Discharge lamp operating apparatus and method

(57) An apparatus for operating a high intensity discharge lamp that minimizes discharge arc curvature to form a straight discharge arc and thereby eliminates variations in the discharge arc color caused by cataphoresis is disclosed. The apparatus outputs a synthesize wave having a waveform with a frequency component of the acoustic resonance frequency to excite a mode straightening the discharge arc, and a waveform of a frequency less that the acoustic resonance frequency whereby the polarity of the waveform having a frequency less than the acoustic resonance frequency changes. The acoustic resonance frequency is determined by the speed of sound in the discharge space, and the length of the discharge space intersecting the discharge arc.

Fig.7A



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Description

BACKGROUND OF THE INVENTION

1. Field of the invention

The present invention relates to a discharge lamp operating apparatus and method for reducing the discharge arc curvature caused by harmful gravity-induced convection when the discharge lamp is started horizontally (in a non-upright position), and relates particularly to a discharge lamp operating apparatus that is effective with high intensity discharge (HID) lamps.

2 Description of related technologies

HID lamps are widely used today for outdoor lighting because of their high luminous efficacy and long service life. The good color characteristics of metal halide lamps in particular have also led to their use for applications other than outdoor lighting, including interior lighting light sources for audio-visual equipment, and even motor vehicle headlights.

A typical conventional HID lamp operating apparatus is described in the No. 10 Proceedings of the Light Association of Japan, Tokyo Branch. The discharge lamp operating apparatus described in these Proceedings enables stable operation and prevents discharge arc wandering, self-extinguishing, and lamp damage caused by the acoustic resonance unique to HID lamps by supplying a low frequency (several hundred hertz), rectangular wave current to the HID lamp, which is one type of discharge lamp.

While this type of igniter can light and then stably drive an HID lamp in a horizontal position, the effect of gravity-induced convection causes the discharge arc to curve upward in an bowed arc.

When the discharge arc curves, the temperature rise in the top part of the discharge space increases, thus deteriorating the quartz glass defining the discharge envelope, which is perceived as a loss of transparency, and shortening the service life of the lamp. Luminous efficacy also drops due to a drop in the lowest temperature at the bottom of the discharge space.

Metal halide lamps with a shorter arc length have been developed in recent years for use as light sources in audio-visual equipment and motor vehicle headlights, and shorter arc lengths require a higher mercury vapor pressure in the discharge space of the lighted lamp. Increasing the vapor pressure, however, increases gravity-induced convection, thereby increasing the curvature of the discharge arc and further degrading lamp life and efficacy.

The discharge lamp operating apparatus is disclosed in U.S. Patent No. 5,198,727 issued to Allen et al. in which the above problem is addressed. The above problem is further described below with reference to Fig. 14.

As shown in Fig. 14, a waveform diagram of the lamp current of a discharge lamp driven by the discharge lamp operating apparatus disclosed in U.S. Patent No. 5,198,727 teaches that curvature in the discharge arc can be reduced to obtain a substantially straight discharge arc by supplying to the lamp a current to which an ac wave 52 of a certain frequency has been superposed. This certain frequency is one that reduces the effects of gravity-induced convection in the discharge lamp fill on dc current 51 by means of acoustic resonance, and thus straightens the discharge arc.

Straightening the discharge arc reduces the temperature at the top of the discharge space, and thus alleviates one factor contributing to a shorter discharge lamp life. It is therefore possible to achieve a long-lasting discharge lamp and also improve luminous efficacy by raising the temperature of the lowest temperature in the bottom of the discharge space.

With a conventional discharge lamp operating apparatus as described above, however, current always flows in one direction in the discharge lamp, and while the field strength of the discharge space changes with a regular period, the field always moves in one direction. The fill distribution thus becomes unbalanced, and cataphoresis results in inconsistent arc coloring.

An asymmetrical temperature distribution along the electrode axis also occurs with a high temperature on the anode side and a low temperature on the cathode side. As a result of this asymmetrical temperature distribution, the effect of superposing a frequency that excites an arc-straightening mode is small, although the curvature of the discharge arc is still somewhat reduced.

A discharge lamp operating apparatus is also disclosed in the applicant's prior U.S. application Serial No. 08/560,683 filed November 20, 1995 and entitled "DISCHARGE LAMP-LIGHTING APPARATUS" (corresponding to European Patent publication No. 0713352 published May 22, 1996). The inventors of U.S. application Serial No. 08/560,683 are the three present inventors and Makoto Horiuchi and Ryuji Higuchi.

SUMMARY OF THE INVENTION

The object of the present invention is therefore to resolve these problems by providing a discharge lamp operating apparatus for operating a high intensity discharge lamp that minimizes discharge arc curvature to form a substantially straight discharge arc, eliminates variations in the discharge arc color, and avoids cataphoresis.

To achieve this object, according to the present invention, a discharge lamp operating apparatus for operating a discharge lamp having a glass envelope defining a discharge space, comprises:

a generator for generating a first wave signal having a waveform with an acoustic resonance frequency